ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

PROJECT NO. 2 - OPERATIONS AT HIGH TEMPERATURES

Partial Report

On

Sub-Project No. 2-3, Test of the Adequacy and Ranges of Use of Clothing for Jungle Operations

Sub-Project No. 2-18, Effects of Impregnated and Impervious Clothing Upon the Efficiency of Personnel

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Action copies have been forwarded to Requirements Section, AGF for approval and execution.

Project Nos. 2-3, 2-18

24 November 1943

ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 2(2-3,18)
727-3 GNOML

24 November 1943

1. PROJECT: No. 2 - Operations at High Temperatures, Partial Report on Sub-Project No. 2-3, Test of the Adequacy and Ranges of Use of Clothing for Jungle Operations and 2-18, Effects of Impregnated and Impervious Clothing Upon the Efficiency of Personnel.

a. Authority: Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNOHD, dated September 21, 1942.

b. Purpose: To determine the relative physiological loads imposed by various types of clothing upon acclimatized men working in a simulated jungle environment.

2. DISCUSSION:

a. General: The effects of various types of issue clothing and non-standard items were measured during two acclimatization experiments, utilizing thirty (30) enlisted volunteers in the Hot Room of the Armored Medical Research Laboratory. The men were well acclimatized and showed no evidence of deterioration during the period of test of the clothing. Relative changes in heart rate, rectal temperature, water (sweat) loss and subjective reactions during and upon completion of standard work were noted.

b. Procedure: The dry bulb temperature was maintained between 90°F and 91°F and the relative humidity ranged from 92% to 95%. Details of the work regimen are included in the Appendix.

3. CONCLUSIONS:

a. Acclimatized men work with greatest effectiveness and comfort and least burden upon their heat regulating, cardiovascular and sweat mechanisms and have the lowest water requirements when unclothed (wearing only shorts, socks and shoes).

b. Any garment covering a major portion of the body adds a definite and measurable burden which is manifested by marked increases in heart rate, rectal temperature and sweat loss, and by subjective sensations ranging from moderate to extreme discomfort.

c. In order of magnitude of the added load and the undesirable effects produced, the tested garments or ensembles are as follows:

(1) British fireproof overalls, tank crews, one-piece manufactured by T. Ravden and Sons, Ltd., 1942.

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(2) U. S. Army Suit, one-piece, herringbone twill, protective modified with overlapping flaps; union suit, cotton, protective two-piece; socks, wool, light, protective; hood, wool, O.D., protective and gloves, cotton, protective, (Leggings canvas, M1938, O.D., dismounted, protective, and gas mask not worn).

(3) U. S. Army fatigue coveralls, Suit, one-piece, herringbone twill, made fire-resistant at M.I.T. by C.W.S. process of impregnation with 22% antimony oxide and 12% Vinylite VYHH resin.

(4) U. S. Army Suit, one-piece, herringbone twill, unlaundered.

(5) U. S. Army Suit, one-piece, herringbone twill, worn 2-6 months and laundered repeatedly.

(6) U. S. Army Shorts, Cotton.

d. When items (3), (4), and (5) above, are wetted with unevaporated sweat the differences between them become insignificant.

4. RECOMMENDATIONS:

a. That all clothing to be issued for jungle operations be tested on standardized test subjects before acceptance, to determine the physiological burden which is imposed upon the wearer.

b. That all jungle clothing (wool excluded) be thoroughly laundered before use in hot humid environments.

c. When the military situation permits, and when there are no hazards from fauna, flora or solar radiation, men in hot humid climates be permitted to work in minimum amount of clothing.

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Appendix with Figs. 1 & 2

APPENDIX

1. Experimental Conditions and Procedures.

a. Environment: All subjects lived continuously in the Hot Room with the dry bulb temperature at 90° to 91°F and the relative humidity ranging from 92 to 95% during the hours of the test. At night the temperature ranged from 78 to 87°F and the relative humidity varied from 60% to 85%. No radiant heat was added. Air movement was moderately turbulent but not measured. Tests were carried out in the summer and fall months of 1943, after three and four weeks of acclimatization.

b. Experimental Subjects: Thirty (30) enlisted volunteers acted as subjects. Their ages ranged from 19 to 21. All men were in good physical condition when tested. The entire group was taking atabrine (0.1 gms daily, six days a week) without effect on acclimatization or performance.

c. Clothing: The tested garments comprised those in Par 3 c, Conclusions. With all of the combinations of clothing tested (except suit, protective), the following additional items were worn: drawers, cotton; shoes, field or boots, jungle and socks, cotton khaki. These items were also worn during the control test (men as naked as possible) which served as a basis of comparison.

d. Status of the Men: Before being exposed to the hot humid environment the men were trained outdoors for several weeks by road marches, standard one-hour walks and fitness tests. The subjects then entered the Hot Room and were acclimatized.

e. Test procedure: Details of the experiment were similar to those previously reported.*

f. In all tests the subjects completed five standard walks (2.5 miles in 47 minutes) carrying a twenty pound pack. Two successive walks, with a 13 minute period after each walk for obtaining data, were completed in the morning and three in the afternoon. Unless otherwise specified, a dry uniform was used in each walking period from which data were obtained for this report. The usual schedule was:

	Day 1	Day 2
1st walk - A.M.	Test Suit (dry)	Laundered Suit, one-piece, HBT (dry)
2nd walk - A.M.	Laundered suit, one-piece, HBT (dry)	Test Suit (dry)

* Report on Studies of Men in Simulated Desert Heat, Project No. 2, (2-11,12,13,17), File 727-2, dated April 3, 1943. Report on Studies of Men in Simulated Jungle (Humid) Heat, Project No. 2(2-7,11,13,15,17,19), File 727.3 GNOML, dated October 18, 1943.

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	Day 1	Day 2
3rd walk - P.M.	Shorts	Shorts
4th walk - P.M.	Test Suit (wet)	Laundered Suit, one-piece, HBT (wet)
5th walk - P.M.	Laundered Suit, one-piece, HBT (wet)	Test Suit (wet)

g. Food, water, sleep: Regular army fare was obtained from the company mess. All drinking water had salt added to a concentration of 0.1%. Men slept eight or more hours a night.

h. Observations:

(1) General appearance and subjective reactions were noted continuously and records kept of vigor, sweating, flushing, headache and gastroenteric and cardiovascular disturbances.

(2) Temperature - rectal temperature was taken (with a clinical thermometer) at the beginning and end of each work period.

(3) Heart rate - at the beginning of each work period the resting pulse was taken in the erect position. At the end of each work period a count was made with the subject marking time.

(4) Weight - the weight, within 10 grams, was obtained before and after each work period. The subject stripped and dried off the sweat. Water intake and urine output were recorded so that the loss for each hour could be calculated.

(5) The clothes were weighed before and after some of the work periods.

2. Results:

a. Subjective manifestations: Without exception, the subjective sensations of discomfort agreed with the objective measures of the several physiological functions. The suit which produced the highest rectal temperature, heart rate and sweat loss also caused the most severe discomfort and feeling of warmth, and produced most fatigue. Two suits caused peculiar sensations in addition to those arising from the added physiological load imposed. The British fireproof suit was uncomfortable to the skin because of its heavy rubbery texture. The odor of the anti-gas outfit was disagreeable.

b. Effects on the skin: All men living and working in the hot room developed prickly heat, folliculitis and skin infections in regions

where the clothes rubbed the skin and where skin surfaces rubbed together. Suits issued new and worn daily in earlier experiments seemed to produce more troublesome skin lesions than did old fatigue uniforms.

c. Physiological effects:

(1) Comparisons of the physiological effects produced by the several uniforms and cotton shorts alone are presented in Figures 1 and 2. In Fig. 1 the columns represent the averaged results from 2 walks on 2 different days for each of three subjects. An exception is the British fireproof suit, the data for which were obtained from only two of these men. They wore the suit for only a single walking period.

(2) The C.W.S. anti-gas outfit was worn for a single walk by two men not subjects in the other experiments. The men were small, exceptionally fit and well acclimatized. Data from these walks are plotted in Figure 2, where comparison is made between one walk with the protective outfit and the averaged data from 3 walks in old suits, one-piece HBT. It is not possible to compare the anti-gas outfit with the suits tested on other subjects but it is at best no better and probably worse than any other suit tested.

(3) With these exceptions all types of suits were tested on many subjects on several days and the data in Fig. 1 are characteristic of the entire group. The British fireproof suit imposed a very heavy load on the men which resulted in an average pulse rate of 164, rectal temperature of 102°F, and sweat loss of 1565 ml per walking period. The suit was very uncomfortable, and probably could not have been tolerated for any extended period of work in this environment. The anti-gas outfit probably imposed a greater burden but the use of different subjects prevents an exact comparison. The practical importance of the added heat load may be seen from consideration of the water requirements for a division of 10,000 men. Working 8 hours a day under climatic conditions like those of the tests the division, if clad in the British fireproof suit, would require 30,000 gals. of drinking water a day, whereas the same division wearing shorts would require only 15,000 gal/day.

(4) The Army C.W.S. fire-resistant suit was next in severity, though it was more comfortable than the British fireproof suit.

(5) A slightly less severe burden was imposed by the new, unworn and unlaundered Suit, one-piece, herringbone twill (identical results have been obtained with the Suit, one-piece, jungle which is made of the same material). Worse effects were invariably produced

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by suits which were new and unlaundered than (1) similar suits which had been worn for a long time or (2) the same suit after it had been worn and laundered repeatedly. Much of the additional burden imposed by the newness of the suit was lost within 10 days of continued wear, when the suit was rinsed out every night, but not laundered with soap. Under the conditions of the test, the suit was soaking wet during the day when the heat and humidity were high, and sweat was running off.

(6) Of all the uniforms tested, the Suit, one-piece, herringbone twill, which had been worn and laundered repeatedly, imposed the least additional burden upon the men during the routine test walk. The following table gives the averaged results for 15 men during 2 standard walks, with suits dry at start of the walk.

TABLE 1

Condition of Uniform	Pulse	Rectal Temp.	Sweat loss (ml)
Old Suit, one-piece, herringbone twill	123	100.1	963
New Suit, one-piece, herringbone twill	135	100.3	1089

The additional sweat loss imposed by the new suit expressed in terms of added water requirement for a division (10,000 men) amounts to approximately 350 extra gallons for an hour's work. This holds true only for a dry uniform.

(7) When the suits are saturated with sweat the differences disappear. The following data, taken from another group of subjects are averaged figures from the second and fourth walking periods when the test suits were saturated with sweat. (Suits worn all work periods this day).

TABLE 2

Condition of Uniform	Pulse	Rectal Temp.	Sweat loss (ml)
Old Suit, one-piece, herringbone twill	123	100.4	1005
New Suit, one-piece, herringbone twill	122	100.4	1024

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(8) The capacity of the suits to absorb and hold water did not vary significantly with age, wear or laundering; i.e. the gain in weight (sweat) of old and new suits for the same subjects was the same (Table 3). It varied for different subjects with the quantity of sweat secreted and evaporated.

TABLE 3
Gain in Weight (grams) of Test Suits Per Work Period

	Old Suit (Laundered, worn)				Unlaundered New Suit Initial Trial
	Test 1	Test 2	Test 3	Average	
Subject A	447	565	719	574	604
Subject B	995	1170	1265	1143	1120
Average	---	---	---	859	862

In all other instances the trend was the same. Note the large difference in sweat loss between Subject A, a small man (130 lbs) and Subject B, a large man (178 lbs). Studies on evaporation differences are in progress and preliminary observations indicate that, though small, these differences may be measurably higher with the laundered garment.

(9) It has been observed repeatedly that the new unlaundered suit does not become wet as rapidly and does not cling to the skin as readily as the old garment. Therefore, larger differences between suits would probably appear after more strenuous work for short periods, than was true in these tests, since these were carried out for the customary standard work period, which was sufficiently long for both suits to become thoroughly wet, thus obscuring any small differences in rate of wetting.

(10) It is essential that all tests on garments in hot humid environments be done with due consideration for obtaining good fit (or at least the same fit) of all garment tested. Otherwise, large errors in estimating heat load may occur as a result of differences in ventilation arising from differences in fit of garments, variation in size of openings at the neck and sleeves, buttons left unfastened, or pants or sleeves rolled up.

(11) Tests designed to determine the physiologic loads imposed by clothing in hot humid regions or in laboratory hot rooms

should be controlled by:

(a) Using subjects who are well trained in the test work and who are thoroughly acclimatized to work in hot humid environments.

(b) Testing with trained but unacclimatized subjects.

(c) Comparison of the effect of repeated laundering and wear on the heat load.

(d) Comparing the effects of dry and thoroughly wet garments.

(e) Using very severe environments for the test. (D.B. 90-92°F, RH 90-95%)

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FIG. 1

EFFECTS OF FIVE TYPES OF CLOTHING UPON SWEAT LOSS, RECTAL TEMPERATURE AND PULSE RATES

(ACCLIMATIZED MEN, TEMPERATURE 90 – 91 °F, RELATIVE HUMIDITY 92 – 95 %)

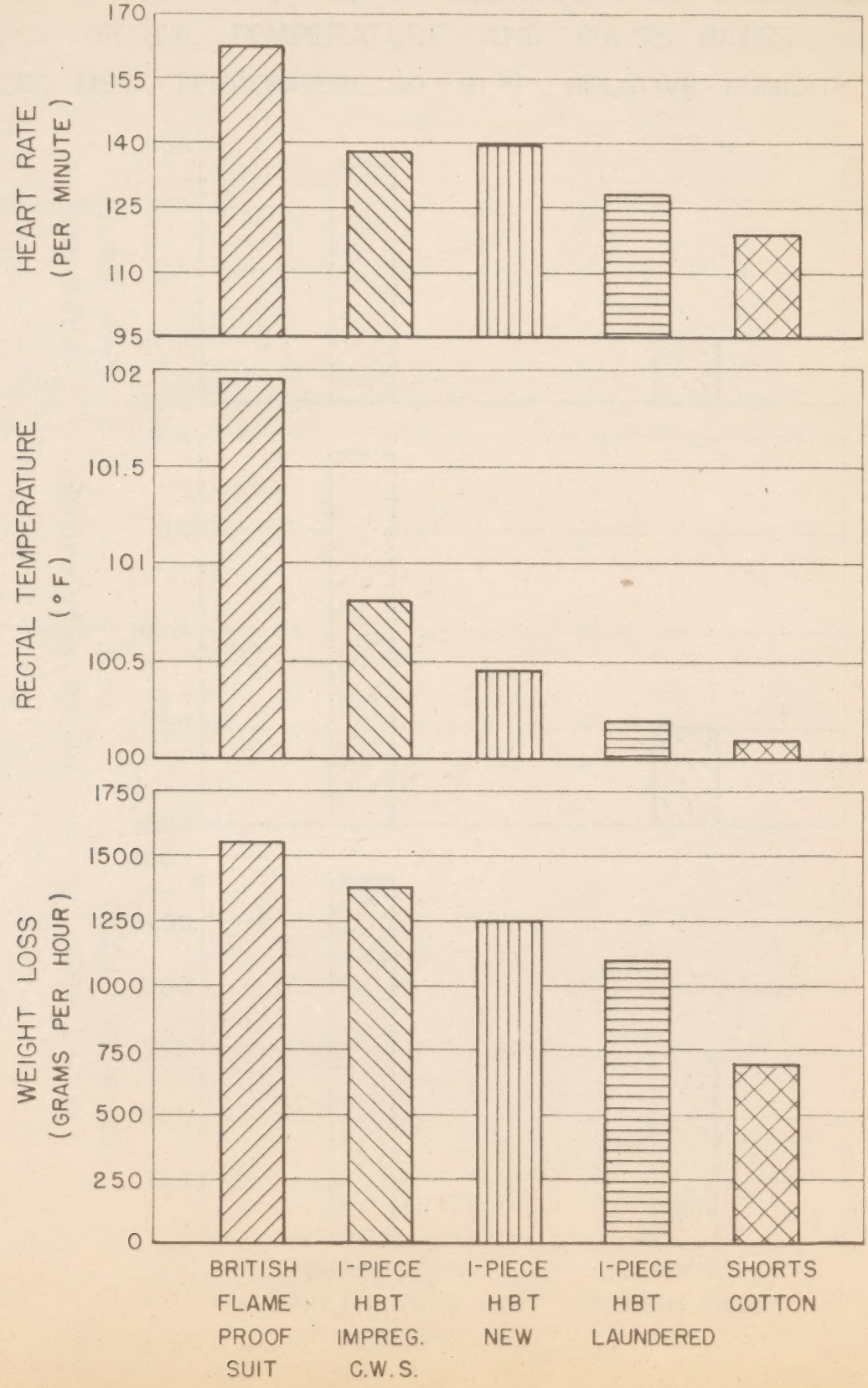

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FIG. 1

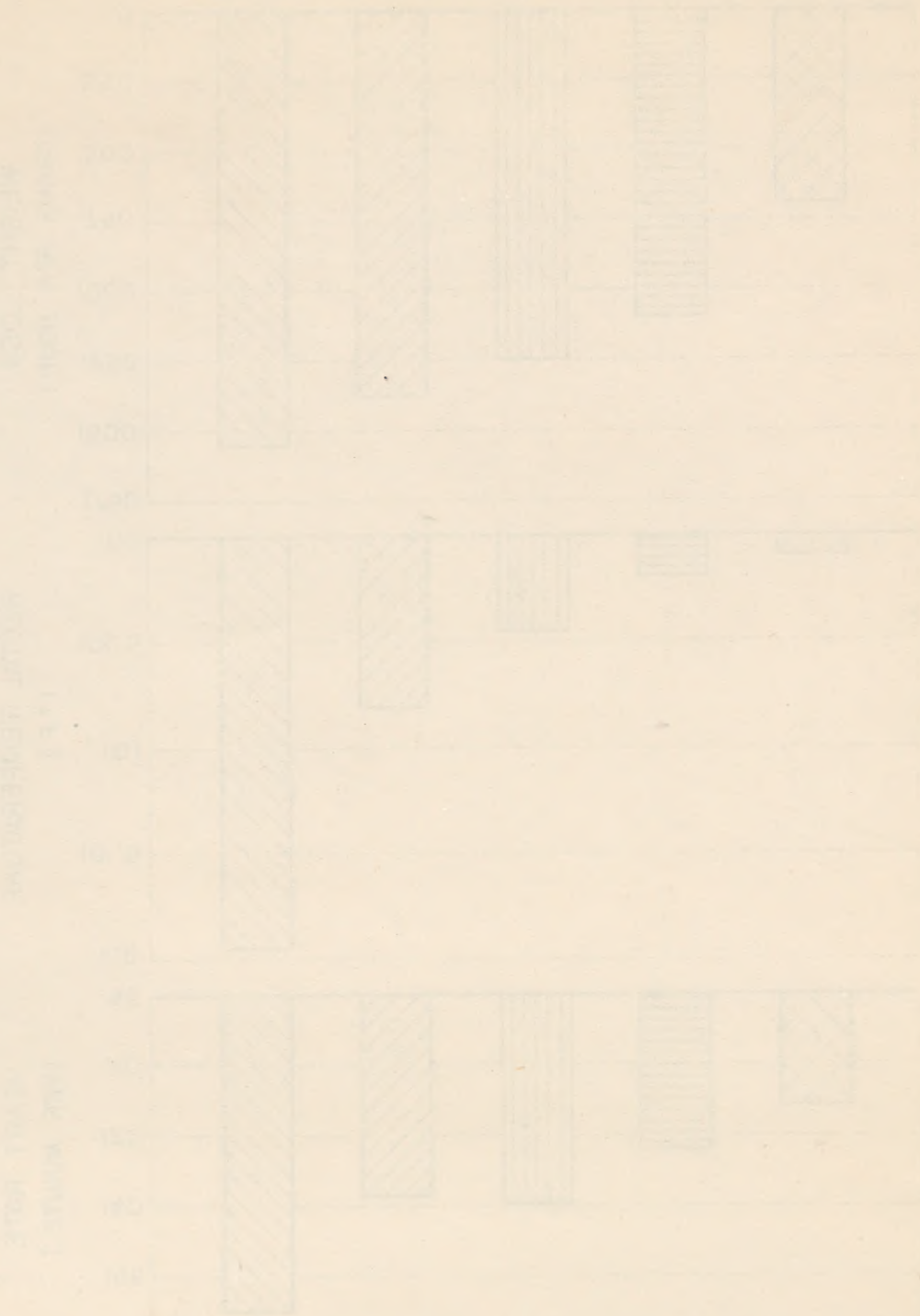

FIG. 2

EFFECTS OF TWO TYPES OF CLOTHING UPON SWEAT LOSS, RECTAL TEMPERATURE AND PULSE RATES

(ACCLIMATIZED MEN, TEMPERATURE 90 – 91 °F, RELATIVE HUMIDITY 92 – 95 %)

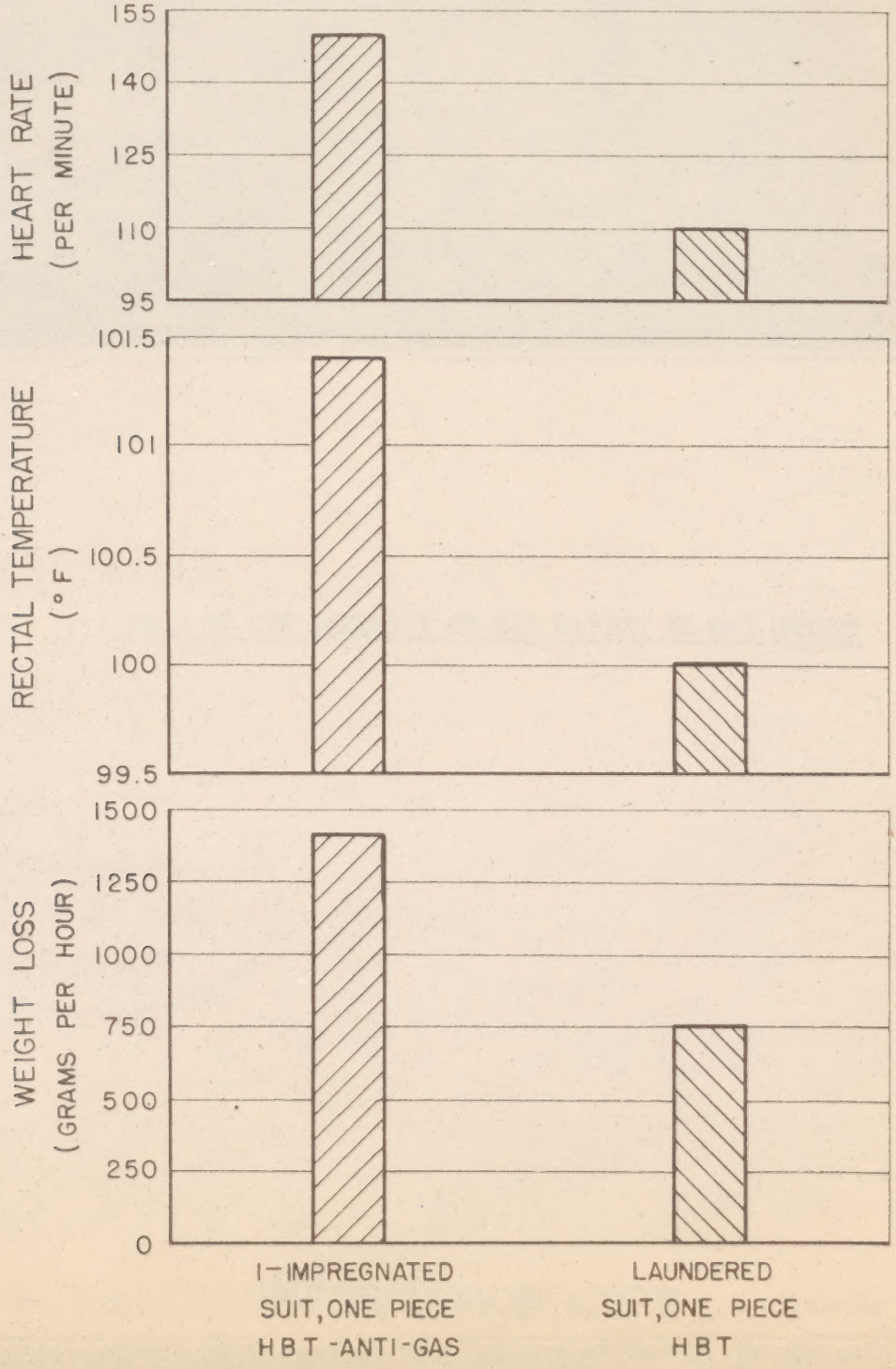

FIG. 2

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